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## Operating Facilities Programme

**Agreement to the modification: NP/SC 7703 Hinkley Point B and Hunterston B – Boiler  
Tube Failure Safety Case Phase 2b Consolidation, EC352075, Version 005 and  
EC352076, Version 005**

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## EXECUTIVE SUMMARY

### Permission Requested

EdF Energy Nuclear Generation Limited (NGL), the operator and licensee of Hinkley Point B and Hunterston B nuclear power stations, have written to the Office for Nuclear Regulation (ONR) requesting an Agreement or Acknowledgement under Licence Condition (LC) 22(1) to the modification described in the Boiler Tube Failure Safety Case Phase 2b Consolidation, NP/SC 7703.

This Project Assessment Report (PAR) considers this request and recommends providing an 'Agreement' via issue of Licence Instruments (LI) under LC 22(1).

### Background

During 2006 Statutory Outages at Hinkley Point B and Hunterston B Power Stations in July and September respectively a significant number of defects were found in the boiler superheater bifurcations and tailpipes which challenged the validity of the pre-existing safety case. As a result of these findings all four reactors at Hinkley Point B and Hunterston B were shut down for in-vessel inspections of the superheater bifurcations and tailpipes.

Following significant in-vessel inspections and repairs Category 1 justifications were produced to support the return to service of all four reactors at Hinkley Point B and Hunterston B. Constraints were implemented on operating temperatures and timescales to further inspections.

At each subsequent periodic shutdown all accessible superheater bifurcations and tailpipes were inspected. Repairs were carried out where the inspection findings threatened boiler integrity over the following operating period.

Since return to service of the four reactors in 2007 further safety case development work and a programme of plant modifications has continued to reduce the risks arising from Boiler Tube Failures (BTFs). A phased development of the consolidated boiler safety case began in 2010 resulting in phase 2b of the BTF Safety Case which is the subject of this PAR

### Assessment and inspection work carried out by ONR in consideration of this request

ONR has pro-actively engaged with NGL regarding the boilers since the initial shutdown of all reactors at Hinkley Point B and Hunterston B for repairs in 2006. Boiler condition has been considered by ONR when providing permission for restart after each periodic shutdown since 2006. Specialist inspectors, including structural integrity, fault studies, probabilistic safety analysis and human factors, have provided advice and guidance on regulatory requirements throughout development of the safety case and implementation of plant modifications. Specialists have carried out site inspections to review modifications to plant and operating procedures where appropriate.

ONR has assessed the safety case to form a view on the adequacy of the claims, arguments and evidence presented. Specialist disciplines in structural integrity, fault studies, internal hazards, probabilistic safety assessment and human factors have carried out a risk-based assessment, focusing on the higher consequence fault sequences.

### Matters arising from ONR's work

#### Structural Integrity

The structural integrity assessor considered the safety case claims, arguments and evidence to be adequate given that there is a good understanding of components loadings, failure mechanisms and consequences, the effects of reduced operating parameters and periodic inspection, future degradation rates plus the measures in place to ensure the boilers are being operated within the limitations specified within the safety case.

The assessor is content that the methods for establishing the likelihood and magnitude of BTFs used in the consolidated BTF safety case are appropriate given that they are based upon sound engineering principles and methodologies and a conservative guillotine failure fraction. Although some uncertainties are identified in the predictions they are considered appropriate for judging the future potential for boiler tube leaks.

Although carburisation is a potential cause for defect initiation within the bifurcations the current safety case assumes defect initiation and growth is managed based upon operating experience and thus the assessor considers this information is unlikely to have a significant effect upon the current safety claims.

The assessor judged, based upon the evidence reviewed, that the risk of future leaks has been reduced as low as reasonably practicable. This judgement is dependent upon completion of the remaining modifications and safety case enhancements identified within the safety case.

The structural integrity assessor is broadly satisfied with the claims, arguments and evidence laid down within the Licensee's safety case and based upon the information sampled, judged that no significant structural integrity issues have been identified that would prevent agreement of the safety case provided outstanding commitments are completed, the effects of carburisation are monitored and periodic inspection of boiler components continue at appropriate intervals.

### Fault Studies

The fault studies assessor focused on completion of the work committed for Phase 2b of the safety case, considering the recommendations from ONR's assessment of Phases 1 and 2a, and resolution of the main safety issues related to BTF, reactor over-pressure and increased reactivity in combination with increased graphite weight loss, reduction in primary shutdown, enhanced shutdown and nitrogen shutdown protection margins.

The assessment has thus focused on the adequacy of reactor trip, shutdown and overpressure protection for all credible BTF faults and the associated evidence presented in the study of BTF water ingress and its impact on reactivity.

The assessor indicated that the protection claims are adequately supported by the arguments and evidence presented in the safety case. Also the safety case is consistent with relevant ONR standards and guidance, sufficient post BTF shutdown margin is justified for up to 23% core average graphite weight loss but an allowance for uncertainty needs to be included in actual weight loss predictions. Additionally that the plant modifications are considered consistent with the safety case in terms of defence against BTF and mitigation of the potential consequences.

The assessor is content that the safety case is fit for purpose; represents the current understanding of BTF and the availability of appropriate protection and mitigation arrangements at both stations. The assessor recommends that the safety case for BTFs on a shutdown reactor should be considered by ONR when completed.

### Probabilistic Safety Assessment

This probabilistic safety assessment assessor focused on the at power and post trip cooling faults with the potential to result in the highest radiological release. Other aspects of the safety case were not assessed in any detail given that the contribution radiological release is predicted to be low or negligible. The assessor is content that a comprehensive review of credible initiating events leading to a boiler tube leak or failure has been undertaken.

While still a significant contributor to overall station risk improvements have been made as a result of the BTF safety case and through the development of the PSA and risk is within the base safety limit for Target 8 of the Safety Assessment Principles (SAPs) and therefore tolerable. However, the magnitude indicates the importance of meeting commitments to make further plant and or procedural improvements to demonstrate that risks are reduced as low as reasonably practicable (ALARP).

The PSA assessor has not identified any significant issues, from a PSA perspective, that would prevent agreement of the safety case but considers that the outstanding commitments identified in the safety case should be completed in a timely manner to demonstrate risks are reduced ALARP. The assessor recommends that ONR engages with NGL to review the development and use of PSAs to end of station life, focusing on the use of best estimate data and analysis where possible. Additionally ONR should consider the need to undertake further assessment of the risks from BTFs during refuelling operations as part of continued oversight of the BTF safety case.

### Human Factors

The human factors assessment has been informed by consideration of the ONR human factors SAPs with respect to the changes made by NGL and the means by which they have been demonstrated to reduce risks to ALARP. The assessment considered identification and analysis of claimed actions on a sampled basis and sought evidence to satisfy all the human factors SAPs relevant to changes being made.

The assessor is satisfied that NGL have comprehensively identified human actions that can impact on safety when a reactor is at power and a BTF develops. The assessor is broadly satisfied with the estimated task durations as there remains a significant margin to the time available and no undue reliance is placed upon human actions.

The assessor is satisfied that, based on the sample examined, potential issues concerning human resources and workload both within the control room and local to plant have been satisfactorily identified and have already been addressed by changes in procedures or, where there are minor claims upon the human, are now being addressed by engineering change.

The assessor considers that NGL have made the necessary human factors interventions to address the prospect of BTFs and based upon the information sampled, judged that no significant human factors issues have been identified that would prevent agreement of the safety case. The assessor has made recommendations that ONR engage with NGL to further consider operating and training aspects relating to human factors.

### Internal Hazards

The internal hazards assessor focused on:

- The effect of internal hazards on the boiler tube safety case, and the ability of operators to carry out post fault actions to manage the plant and achieve the key safety functions of shutdown, containment and adequate cooling.
- The specific issues of the depressurisation fault with consequential BTF, where there is necessarily a hot gas release to the gas circulator hall, and the

- adequacy of the deterministic safety case presented including the viability of claimed operator actions in areas where hot gas is likely to be present.
- The degree of confidence that NGL has in their modelling of the effects of hot gas releases, jets etc.

The assessment included a site visit and walk down of the gas circulator hall to view the important equipment and its location, to understand the layout of the gas circulator and turbine hall, and how this may affect hot gas and steam release flows and temperature predictions.

The assessor judged that internal hazards during reactor trip, shutdown and overpressure protection for BTF with a coincident or consequential BTF only marginally affect the key safety functions. The assessor's view is that the current modelling is adequate for the purposes of the current BTF safety case submission, but views NGL's work programme of additional studies as important.

The internal hazards assessor is broadly satisfied with the claims, arguments and evidence laid down within the Licensee's safety case for the aspects relating to the relationship between the internal hazards safety cases and those for BTF.

The assessor raised two regulatory issues to monitor the licensee's current work programme of comparative analyses of hot gas releases using bulk models and more detailed computational fluid dynamics models and to consider more severe fires and hot gas releases as part of the assessment of the Hinkley Point B and Hunterston B periodic safety review to gain assurance that there is not a "cliff edge" and that the safety case is secure.

## Conclusions

Based on the sampling undertaken, the specialist inspectors have identified no significant issues that would prevent agreement under LC 22(1) to the Boiler Tube Failure Safety Case Phase 2b Consolidation.

Having taken into account the opinions of the ONR specialist inspectors, I consider that there are no issues that prevent ONR issuing the requested agreement. The Agreement is on the basis of the evidence sampled and that the outstanding commitments are completed in a timely manner.

## Recommendations

Based on the assessment undertaken, it is the recommendation of this PAR that the superintending inspector should:

- sign this PAR, confirming support for the ONR technical and regulatory arguments used to justify issuing Hinkley Point B LI555 and Hunterston B LI555; and
- sign Hinkley Point B LI555 and Hunterston B LI555.

ONR should monitor the regulatory findings raised during assessment of the safety case to ensure outstanding commitments are completed and that the validity of the safety case is not significantly undermined.

## LIST OF ABBREVIATIONS

ALARP	As low as reasonably practicable
BMS	ONR Business Management System
BOP	Boiler Operations Panel
BTF	Boiler Tube Failure
ERGM	Effective Reactor Gas Mass
HOW2	(Office for Nuclear Regulation) Business Management System
INA	Independent Nuclear Assurance
INSA	Independent Nuclear Safety Assessment
LI	Licence Instrument
NGL	EdF Energy Nuclear Generation Ltd
NSC	Nuclear Safety Committee
ONR	Office for Nuclear Regulation
PAR	Project Assessment Report
PSA	Probabilistic Safety Analysis
SAP	Safety Assessment Principle(s)
SOI	Station Operating Instruction
SOT	Steam Outlet Temperature
SRV	Safety Relief Valve
TAG	Technical Assessment Guide(s)
UTJ	Upper Transition Joint

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## 1 PERMISSION REQUESTED

1. EdF Energy Nuclear Generation Limited (NGL), the operator and licensee of Hinkley Point B and Hunterston B nuclear power stations, has written (Refs. 1 and 2) to the Office for Nuclear Regulation (ONR) requesting an Agreement or Acknowledgement under Licence Condition (LC)22(1) to the modification described in the Boiler Tube Failure Safety Case Phase 2b Consolidation, NP/SC7703.
2. This Project Assessment Report (PAR) considers this request and recommends providing an 'Agreement' via issue of Licence Instruments (LI) LI555 for Hinkley Point B and LI555 for Hunterston B under Licence Condition 22(1).

## 2 BACKGROUND

3. During 2006 Statutory Outages at Hinkley Point B and Hunterston B Power Stations in July and September respectively a significant number of defects were found in the boiler superheater bifurcations and tailpipes which challenged the validity of the pre-existing safety case. As a result of these findings all four reactors at Hinkley Point B and Hunterston B were shut down for in-vessel inspections of the superheater bifurcations and tailpipes.
4. Following significant in-vessel inspections and repairs Category 1 justifications to support the return to service of Hinkley Point B and Hunterston B Reactors 3 and 4 (Refs. 3 and 4) were produced. The key constraints of these were:
  - The Reactors were to operate at a reduced power output in order to reduce the metal temperature of the bifurcations to ~470°C. This was achieved by the reduction in superheater (steam) outlet temperature (SOT) to ~450°C. This reduction in temperature was to essentially eliminate creep damage by significantly reducing both defect growth and defect initiation;
  - Following return to service, the reactors initially operated for a maximum of two years (seven months for Hunterston B Reactor 3), at which time further inspections of the superheater bifurcations and tailpipes were to be performed;
  - 3 quadrant operation was not permitted on Hunterston B Reactors 3 and 4, and in addition load cycling during refuelling operations was limited in order to minimise the number of transients and cycles the plant was subjected to during the subsequent period of operation and,
  - The implementation of the restriction in steam operating temperature and associated operating constraints on the reactors were monitored and evaluated by the formation of a dedicated Boiler Operations Panel (BOP).
5. At each subsequent periodic shutdown all accessible superheater bifurcations and tailpipes have been inspected. Repairs have been carried out where the inspection findings have threatened boiler integrity over the following operating period. The evidence from these inspections enabled the inspection period to be increased from two to three years in 2010, justified by NP/SC 7580 (Ref. 5).
6. Since return to service of the four reactors in 2007 further safety case development work and a programme of plant modifications has continued to reduce the risks arising from Boiler Tube Failures (BTFs). In 2010 Phase 1 of the BTF Safety Case (Ref. 6) was completed and this outlined commitments for Phase 2. In line with a strategy for demonstrating a progressive reduction in BTF risk an interim safety case update (Ref. 7), referred to as Phase 2a, was developed. This identified the plant modifications and procedural enhancements completed at that time. Phase 2b of the BTF Safety Case (Ref. 8) is the subject of this project assessment report.

### 2.1.1 SUMMARY OF LICENSEE'S SAFETY CASE

7. The licensee's safety case (Ref. 8) presents a summary of the consolidated boiler tube failure safety case for the boilers at Hinkley Point B and Hunterston B in light of the defects identified in 2006. A phased approach to development of the safety case has been taken to reduce BTF risks.
8. The full safety case justification is presented in the Consolidated Boiler Tube Failure Safety Case Keystone Document (Ref. 9).
9. The nuclear safety issues associated with boiler operation are mainly the effects of steam and water ingress to the primary coolant, leading to the potential for:
  - Reactor over-pressure and the threat to reactor coolant pressure boundary integrity.
  - Moisture ingress into the gas circulator motor compartment and associated electrical and oil systems with resultant gas circulator failure and loss of forced gas circulation.
  - Degradation of natural circulation cooling due to accumulation of steam or water within the primary coolant.
  - An effect on reactivity and shutdown margins due to accumulation of steam within the graphite core.
  - Loss of reactor coolant via the BTF leak site and boiler vent valves, boiler safety relief valves (SRVs) or reactor SRVs.
10. The safety case recognises that there is the potential for leaks to occur during normal operation, following a reactor trip, during on-load refuelling and during reactor shutdown operations.
11. The safety case addresses nine claims and presents the arguments and evidence to support them. These are:
  - Claim 1: The loadings on the susceptible boiler pressure boundary components and the degradation mechanisms acting on these components are understood.
  - Claim 2: Boiler operating limits, inspection and acceptance criteria are set to ensure a low likelihood of component failure.
  - Claim 3: The likelihood and magnitude of steam ingress from BTF events has been quantified.
  - Claim 4: Adequate reactor trip, shutdown and overpressure protection has been substantiated for a wider range of BTF faults.
  - Claim 5: Forced gas circulation cooling capability has been substantiated for a wide range of BTF faults.
  - Claim 6a: Natural Circulation will provide adequate post trip cooling for credible fault sequences involving loss of gas circulators where reactor pressure is sustained above a certain level
  - Claim 6b: High Pressure Reactor Internal Flooding will not reach levels which will jeopardise either forced gas circulation or natural circulation.
  - Claim 6c: The risk from Reactor Internal Flooding associated with feeding fault boilers with low pressure feed is acceptable.
  - Claim 7: The safety case encompasses all credible BTFs that could occur during at power, post trip and shutdown conditions, including consequential BTFs following all relevant faults and hazards.
  - Claim 8: The risk from BTF fault and hazard sequences is Tolerable and As Low as Reasonably Practicable (ALARP).
  - Claim 9: Appropriate measures are in place to ensure reactors are operated within the BTF safety case assumptions.

12. Claims one, two and three provide the main substantiation of the structural integrity of the boilers and are supported by evidence compiled within the Boiler Compendium. The Boiler Compendium consists of four reports comprising the head document and three supporting annexes dealing with each of the key components of the boilers. The documents are:
  - Boiler Compendium Head Document (Ref. 10): provides generic information relevant to boiler components in general
  - Boiler Compendium Annex 1 (Ref. 11): considers the superheater bifurcations
  - Boiler Compendium Annex 2 (Ref. 12): considers the superheater tailpipes including pintle/tailpipe weld, pintle/tubesheet weld (Hinkley Point B only), subheaders and associated pipework
  - Boiler Compendium Annex 3 (Ref. 13): considers the upper transition joints (UTJs)
13. Claims four to eight deal with the faults and hazards from BTFs impacting on the safe operation of the reactors and the measures in place to mitigate them.
14. Claim nine deals with the technical specifications and operating instructions required to ensure the reactors are operated within the limits of the safety case
15. The licensee's safety case (Ref. 8) identifies three commitment summaries for further work associated with the justification. These are expanded further in Tables 1, 2 and 3 of Ref. 8 and also identified within Table 24 of the Keystone Document (Ref. 9). The commitments relate to safety case work, plant and procedural enhancements, ALARP assessments and feasibility studies. These commitments relate to ensuring adequate protection against credible BTF related fault and hazard sequences.

### **2.1.2 PLANT CONDITION**

16. To provide protection against the consequences of BTFs a number of safety case, plant and procedural enhancements have been identified to improve protection in the event of a boiler tube failure. These enhancements include:
  - Reduced operating temperatures to minimise future degradation of boiler components
  - Regular inspection to identify and repair/replace defective components.
  - Gas circulator endurance modifications to protect against failure due to moisture ingress.
  - Vessel over pressure protection equipment
  - Effective Reactor Gas Mass monitor
  - Relief system bursting disc
  - Seismic hardening of auxiliary steam and CO<sub>2</sub> supplies
  - Changes to technical specifications to implement new boiler operating conditions and protection systems
  - Changes to maintenance schedules, drawings and manuals
  - Changes to the station safety case documents to reflect the BTF safety case
  - Changes to station operating instructions relating to the BTF safety case
  - Operator training for implementation of operational changes
17. Most of the enhancements have now been completed but there are some aspects still outstanding. The outstanding issues are identified within Table 24 of the Keystone Document (Ref. 9) and summarised in Ref. 8 and Tables 1, 2 and 3 of Ref. 8. None of these relate to physical improvements of the main boilers but to protection systems, safety cases or procedures with a view to reducing the likelihood of a BTF.

18. Incomplete enhancements include provision of a second moisture analyser in each quadrant at Hinkley Point B, a hard wired backup to the effective reactor gas mass high alarm, completion of seismic qualification and functionality of CO<sub>2</sub> system.

### **3 ASSESSMENT AND INSPECTION WORK CARRIED OUT BY ONR IN CONSIDERATION OF THIS REQUEST**

#### **3.1 ASSESSMENT UNDERTAKEN**

19. ONR has pro-actively engaged with NGL regarding the boilers since the initial shutdown of all reactors at Hinkley Point B and Hunterston B for repairs in 2006. Boiler condition has been considered by ONR when providing permission for restart after each periodic shutdown since 2006. Specialist inspectors, including structural integrity, fault studies, probabilistic safety analysis and human factors, have provided advice and guidance on regulatory requirements throughout development of the safety case and implementation of the plant modifications. Where appropriate specialists have carried out site inspections to review modifications to plant and operating procedures.

20. In order to form a view on the adequacy of the claims, arguments and evidence presented, ONR assessed the safety case, Ref. 8. The selection of specialist disciplines to assess the case was risk-based, focusing on the higher consequence fault sequences.

- Structural Integrity (Section 3.1.1)
- Fault Studies (Section 3.1.2)
- Probabilistic Safety Analysis (Section 3.1.3)
- Human Factors (Section 3.1.4)
- Internal Hazards (Section 3.1.5)

21. Summaries of the specialist assessments are provided below:

#### **3.1.1 STRUCTURAL INTEGRITY ASSESSMENT**

22. This section provides a summary of the ONR structural integrity assessor's assessment (Ref. 14) of the BTF safety case (Ref. 8) and highlights where previous structural integrity assessments have been completed in support of continued operation.
23. After the reactors were shut down for inspection and repair in 2006 ONR assessed (Refs. 15 to 22) the structural integrity aspects of the justifications for return to service. Acceptance was based on inspection and repair of existing defects, understanding of the damage mechanism, modified operating conditions, acceptable safety margins, reduced inspection intervals and further development of safety case improvements. At each subsequent periodic shutdown the condition of the boilers was considered in the ONR return to service assessments (Refs. 23 to 25 and 26 to 29).
24. Safety Assessment Principles (SAPs) (Ref. 30) and Technical Assessment Guidance (TAG) (Ref. 31) suggest that structures should be free from significant defects and that they should be defect tolerant. The SAPs (Ref. 30) also indicate that effective management of ageing and degradation is needed to deliver the safety functions of the components for the lifetime of the facility. The structural integrity assessment has considered these and other relevant SAPs, for the BTF safety case at Hinkley Point B and Hunterston B, in conjunction with the ALARP principle.
25. There are a number of outstanding modifications or enhancements identified in the safety case but none of these are considered to relate directly to the structural integrity aspects of the main boiler components but are related to ensuring adequate protection

against credible BTF related fault and hazard sequences. On this basis the assessor has not considered the outstanding modifications identified within Tables 1, 2 and 3 of Ref. 8 within the structural integrity assessment of the consolidated BTF safety case.

26. The basis of the structural integrity safety case is investigation and management of degradation, understanding the potential for and consequences of leaks and ensuring compliance with established operating conditions. To this end the sections of the consolidated BTF safety case that directly related to structural integrity safety case are Claims 1 to 3 and 9.
27. Claim 1 is supported by arguments and evidence to substantiate that the components loads and failure mechanism are understood such that failure can be predicted and avoided during future operation of the boilers. Six arguments and associated evidence are presented and aim to show that integrity can be assured by consideration of the most critical components and that future degradation can be managed.
28. Claim 2 is supported by arguments and evidence that the reduced operating limits, boiler operating conditions and periodic inspection are appropriate to minimise the potential for future failure.
29. Initial inspection periodicity for the new operating conditions was two years, increasing to the original three years in 2009. The increase was justified based upon metallurgical and inspection results indicating reduced growth rates, growth calculations and a conservative repair policy. However, to confirm that there is no future significant defect growth, the assessor considers that defectiveness should continue to be monitored during boiler inspections at appropriate intervals.
30. A recent review, Ref. 32, has enabled the inspection interval to be increased to six years to enable deferral of vessel entry at Hinkley Point B Reactor 3 which has a significant dose benefit for the inspection operators. The justification for this deferral is based upon assessment of previous inspection data and a creep analysis at the current reduced operating temperature. A better understanding of defect growth rates and improvements in inspection is likely to be used to support a future strategy to increase inspection periodicity at the remaining reactors at Hinkley Point B and Hunterston B. The assessor considers that this strategy will require appropriate justifications to be developed for each such deferral.
31. Claim 3 is supported by arguments and evidence for the consequences of BTFs informing the probabilistic safety assessment and fault studies assessments. This includes identification of ingress rates for a guillotine failure location and the potential for consequential failures of other boiler components.
32. Failure probabilities for more than two bifurcation or four Upper Transition Joint (UTJ) failures during a reactor trip are sufficiently low to be discounted. Additionally failure probabilities for two or more bifurcation or UTJ failures during depressurisation faults and seismic events are sufficiently low and can also be discounted. Failure probabilities for multiple tailpipe to pintle weld failures are considered to be sufficiently low to be discounted. This assessment shows the potential for a significant number multiple BTF is highly unlikely, addressing initial concerns within the structural integrity return to service assessment, Ref. 22.
33. Claim 9 is supported by arguments and evidence that measures are in place to ensure the boilers are being operated within the limitations specified within the safety case. This included ensuring operational documentation contains appropriate limits and margins to those limits, compliance methods contain sufficient conservatism and that the case is robust.

34. The assessor considered that the evidence provided indicates significant effort has been expended in understanding the cause of leaks in the boiler components at Hinkley Point B and Hunterston B and in predicting future degradation. Modifications have been made to the operating conditions to reduce degradation rates. Inspection techniques have been employed to identify further degradation to reduce the likelihood of future leaks. Modelling has been carried out to predict the potential frequency of future leaks for use within the probabilistic and fault studies aspects of the safety case. Evidence from this work has shown a significant reduction in degradation rates which has been reflected in the inspection results from periodic shutdowns subsequent to restart after all the reactors were shut down in 2006.
35. Recent evidence has suggested that carburisation is a potential cause for defect initiation within the bifurcations. The current safety case assumes defect initiation and growth is managed based upon operating experience and thus the assessor considers this information is unlikely to have a significant effect upon the current safety claims but that ONR should monitor any potential safety case impact relating to this degradation mechanism.
36. The assessor judged, based upon the evidence reviewed, that the risk of future leaks has been reduced to ALARP. This judgement is dependent upon completion of the remaining modifications and safety case enhancements identified within the safety case. Additionally the assessor made a number of recommendations relating to future commitments, carburisation and monitoring of defect growth. These recommendations are identified at the end of this section.
37. The assessor is content that the methods for establishing the likelihood and magnitude of BTF used in the consolidated BTF safety case are appropriate given that they are based upon sound engineering principles and methodologies and a conservative guillotine failure fraction. Although some uncertainties are identified in the predictions they are considered appropriate for judging the future potential for boiler tube leaks.
38. The structural integrity assessor is broadly satisfied with the claims, arguments and evidence laid down within the Licensee's safety case and based upon the information sampled, judged that no significant structural integrity issues have been identified that would prevent agreement of the safety case.
39. The assessor recommended:
  - That the outstanding commitments should be completed in a timely manner and that ONR monitors progress. This should be the subject of an ONR regulatory issue.
  - That ONR monitors the potential implications of carburisation on the safety case for boilers at Hinkley Point B and Hunterston B. This should be the subject of an ONR regulatory issue.
  - That, to ensure predictions remain valid, periodic inspections of boiler components should continue at appropriate intervals.
  - ONR should provide, from a structural integrity perspective, an 'Agreement' to the Licensee's safety case.

### **3.1.2 FAULT STUDIES ASSESSMENT**

40. This section provides a summary of the ONR fault studies assessor's assessment (Ref. 33) of the BTF safety case (Ref. 8) and highlights where previous fault studies assessments have been completed in support of continued operation.
41. After the reactors were shut down for inspection and repair in 2006 ONR assessed (Ref. 34) the fault studies aspects of the justifications for return to service (Refs. 3 and

- 4). Acceptance for return to service at reduced power and temperature limits was given. The assessment noted that the number of judgements made needed to be reduced through appropriate analysis and plant modifications. The assessment also highlighted the need to develop a consolidated safety document which is coherent, complete and demonstrates that long term risks related to BTF have been reduced to ALARP.
42. In 2010 ONR fault studies assessed (Ref. 35) the Hinkley Point B and Hunterston B Power Stations BTF Safety Case Phase 1 Consolidation safety case (Ref. 6). The assessment indicated that the potential for BTF, as a consequence of other plant faults, had been exhaustively reviewed and the significant initiating events and frequencies had been identified. Shortfalls against the SAPs were identified but the safety case demonstrated a thorough approach to identifying limits and conditions and improvements to plant and procedures to mitigate the risks. The safety case (Ref. 6) also provided a suitable scope and structure for Phase 2 of the consolidated safety case. The main recommendations of the assessment (Ref. 35) were that a statistical analysis of leak probabilities should be a high priority, a more comprehensive range of design-basis and best-estimate transient analyses is required and that moisture detection during shutdown should also be a priority.
43. The ONR fault studies specialist assessed (Ref. 36) the Hinkley Point B and Hunterston B Power Stations BTF Safety Case Phase 2a Consolidation safety case (Ref. 7) in 2012. The assessment made a number of observations on the status of work related to fault studies. These included a reduction in leak rates and frequency of BTFs, confirmation of the adequacy of natural circulation cooling, improved protection against reactor flooding and optimisation of station operating instructions and technical specifications. The assessment concluded that NGL has made satisfactory progress in improving the design-basis fault analysis for BTF at Hinkley Point B and Hunterston B. The scope of work proposed for Phase 2b was considered appropriate.
44. The current fault studies assessor's assessment (Ref. 33) has focused on completion of the work committed for Phase 2b, considering the recommendations from ONR's assessment of Phases 1 and 2a, and resolution of the main safety issues related to BTF. These are considered to be:
- Reactor over-pressure and threat to integrity of the reactor coolant pressure boundary (reactor pressure vessel).
  - Increased reactivity due to water ingress to the core and, in combination with increased graphite weight loss, reduction in primary shutdown, enhanced shutdown and nitrogen shutdown protection margins.
45. The fault studies assessor has sampled those elements of the safety case (Ref. 8) and its supporting documents from a fault studies point of view and assessed them against the applicable ONR guidance in order to make a judgement as to the adequacy of the safety case.
46. The assessment (Ref. 33) has thus focused on the adequacy of reactor trip, shutdown and overpressure protection for all credible BTF faults (Claim 4 of Ref. 8) relating directly to fault studies and the associated evidence presented in the study of BTF water ingress and its impact on reactivity (Ref. 37).
47. The assessment (Ref. 33) considered the commitments closely related to fault studies including plant modifications, analyses, specific studies, additional work relating to a shutdown reactor and the clarity of the safety case. The assessor noted that the case presents clear tabulated lists of the work that remains to be completed and that progress will be monitored by the boiler programme board and that ONR will be informed by regular progress review meetings. Considering the above observations the

assessor judged that from fault studies point of view the work committed to for Phase 2b has made good progress and that the remaining work is clearly identified.

48. The arguments supporting Claim 4 are that two lines of protection are available for frequent faults and one line of protection is available for all credible infrequent faults relating to reactor trip, shutdown and reactor overpressure protection. The assessor indicated that, from fault studies perspective, Claim 4 is adequately supported by the arguments and evidence presented in the safety case and its keystone document (Refs. 8 and 9).
49. The assessor sampled the calculations of water ingress and its impact on reactivity reported in Ref. 37 which supports Argument 4.2 of Claim 4. The assessment found that the methodology is appropriate and that the shutdown margin sensitivity to most important factors has been considered.
50. The assessor indicates that, from a fault studies perspective, the safety case is consistent with the relevant ONR standards and guidance. Sufficient post BTF shutdown margin is justified for up to 23% core average graphite weight loss but an allowance for uncertainty needs to be included in actual weight loss predictions. Additionally the introduced and proposed plant modifications are considered consistent with the safety case in terms of defence against BTF and mitigation of the potential consequences.
51. The assessor is content that, from fault studies point of view, the safety case is fit for purpose; represents the current understanding of BTF and the availability of appropriate protection and mitigation arrangements at both stations.
52. The assessor recommended:
  - ONR should provide, from a fault studies perspective, an 'Agreement' to the Licensee's safety case.
  - In view of the Licensee's commitment to produce a safety case for BTFs on a shutdown reactor, the assessor recommends that it should be considered by ONR when completed.

### 3.1.3 PROBABILISTIC SAFETY ANALYSIS (PSA)

53. This section provides a summary of the ONR probabilistic safety assessment (PSA) assessor's assessment (Ref. 38) of the BTF safety case (Ref. 8). The assessment focused on BTFs occurring at power operations, including consequential failures during post trip cooling, which have the potential to result in the highest radiological release (Dose Band 5 category). These are accidents on a facility that could result in an off-site dose to a person greater than 1 Sievert (Sv) (Target 8 of ONRs SAPs), which has a frequency target - basic safety level and basic safety objective of  $1 \times 10^{-4}$  and  $1 \times 10^{-6}$  per year respectively. Other aspects of the safety case were not assessed in any detail given that the radiological release is predicted to be low or negligible.
54. The assessment has been informed by consideration of the ONR fault analysis SAPs (Ref. 30), TAGs (Ref. 31) and existing ONR regulatory issues. The assessment assumes that any changes made as a result of the BTF safety case have been implemented satisfactorily, and any reliability claims made in the PSA for systems, structures and components are met. The adequacy of the shutdown PSA for BTFs and risks from BTFs during low power refuelling are not considered as they are the subject of separate safety documents.
55. The assessor judged that the success criteria used in the PSA are based on conservative design basis analysis. Although NGL had analysed a number of

sequences using a best estimate approach these values were not used in the event tree analysis supporting the PSA. NGL is content that best estimate data had been used to assign initiating event frequencies and to predict the reliability of systems / safety measures. ONR's expectation is that the PSA should be a best estimate analysis tool and areas of conservatism should be reduced, not only to avoid impacting on the quantitative analysis, but to ensure that valuable insights are drawn from the PSA results. However, this is a generic PSA issue and not specific to the BTF safety case. On this basis it is recommended that ONR engages with NGL to review the development and use of PSAs to end of station life, focusing on the use of best estimate data and analysis where possible.

56. The identification of risk reduction measures in the safety case has been considered by the assessor to determine whether further reasonably practicable improvements could be made. The dominant contributors to risk have been identified but it was unclear how the reliability of a feature is considered in the risk assessment and how the information was used to identify potential risk reduction options. NGL has provided clarification and additional evidence to demonstrate that the risks have been reviewed to identify potential risk reduction measures. The assessor is content that the outcome of analysis has been reviewed to identify further risk reduction options to demonstrate risks are being reduced ALARP.
57. The BTF safety case concentrates on the review of the fault and engineering schedules to ensure there is adequate safety provision. NGL described the process undertaken to review all potential initiators that could result in a change in pressure or temperature and therefore impact on the pressure boundary and the likelihood of a boiler tube leak or failure. Based on the discussion with NGL and evidence provided the assessor is content that a comprehensive review of credible initiating events leading to a boiler tube leak or failure has been undertaken.
58. The safety case provides an estimate of the contribution to Dose Band 5 frequency from plant based faults and hazards during at power, shutdown and refuelling operations, for comparison with overall station risk. Although improvements have been made as a result of the BTF safety case and through the development of the PSA, the contribution to Dose Band 5 from those sequences that involve BTFs is significant. However, the Dose Band 5 frequency remains below the base safety level of Target 8 of the SAPs and therefore tolerable. Nevertheless, the magnitude indicates the importance of meeting commitments to make further plant and or procedural improvements to demonstrate that risks are reduced ALARP.
59. The assessor is content that the PSA modelling is sufficiently developed to close the related ONR Issues 715 and 953 and is satisfied that the sufficient evidence had been provided to demonstrate that the PSA claims considered can be met, subject to the following recommendations:
  - ONR should engage with NGL to review the development and use of PSAs to end of station life, focusing on the use of best estimate data and analysis where possible. This should be the subject of an ONR regulatory issue.
  - ONR should consider the need to undertake further assessment of the risks from BTFs during refuelling operations as part of continued oversight of the BTF safety case. This should be the subject of an ONR regulatory issue.
  - The outstanding commitments should be completed in a timely manner to demonstrate risks are reduced to ALARP. This should be the subject of an ONR regulatory issue.
60. The assessor has not identified any significant issues, from a PSA perspective, that would prevent agreement of the safety case.

### 3.1.4 HUMAN FACTORS

61. This section provides a summary of the ONR human factors assessor's assessment (Ref. 39) of the BTF safety case (Ref. 8). The assessor highlights previous human factors assessments and examines whether the issues raised are now suitably resolved and examines whether overall the case for human factors is satisfactorily made.
62. The assessment has been informed by consideration of the ONR human factors SAPs with respect to the changes made by NGL and the means by which they have been demonstrated to reduce risks to ALARP. The assessment considered identification and analysis of claimed actions on a sampled basis and sought evidence to satisfy all the human factors SAPs relevant to changes being made.
63. While the demonstration of the manner by which human factors has been integrated into the changes to engineering design, procedures, training and operation of the plant is not considered ideal, overall the assessor is satisfied that suitable human factors expertise has been involved where required. The shortfalls identified, and their impact on ONR's consideration of the BTF safety case, are considered below.
64. The assessor is broadly content that the question of reliance on humans has been appropriately considered and addressed, and automation has been employed to reduce undue reliance on humans, where action is required within short timescales.
65. The assessor considers that NGL has taken a systematic approach to the identification of human actions that can impact on safety, and that they have given consideration to a suitable range of operating modes. Whilst some limitations have been identified, the assessor does not consider these to be significant in nature.
66. Task analysis has been used to support human reliability assessment and therefore by definition, supports demonstration of tasks delivering functions important to safety. The scope of task analyses has been predominantly confined to centralised control room tasks, although some consideration has also been given to tasks that are claimed local to plant, mainly in terms of timescales. Whilst there are some reservations about the analysis of potential variability in task durations the assessor is broadly satisfied with the estimates given as there remains a significant margin to the time available.
67. Changes to plant and operation have not necessitated modifications in workstation design although there have been changes to user interfaces. Claims within the safety case are related to the provision of an Effective Reactor Gas Mass (ERGM) alarm, together with the pre-existing alarms and indications for primary circuit pressure. In addition, alarm changes in the gas circulator endurance system have been made consistent with the existing hardwired and data processing system based alarms at each station. Demonstration of the adequacy of user interfaces for claimed tasks is confined to simulations involving one crew for each station and does not consider all potential situations or record operator effectiveness.
68. Given the importance of human actions, the potential for performance variation in failure scenarios and operator responses the assessor considers that a wider demonstration of user interface effectiveness and response times remains to be made.
69. The assessor is content with the systematic identification of task claims and the requirements for personnel competence within tasks that could impact upon nuclear safety and that the design and incorporation of training within the existing training programme would be relatively straightforward. However, no systematic evidence has been provided by NGL to show the effectiveness of the training or that the necessary competence has been achieved from the training given.

70. Notwithstanding this, the assessor considers that operating procedures have been subjected to extensive development processes and simulator trials and that the safety case focus upon safety related actions will have ensured their technical suitability. It is recognised that the execution of necessary BTF procedures can be complex and may be time constrained in some scenarios. It is therefore considered that ONR should undertake an inspection to examine the structure and content of the Station Operating Instruction (SOIs).
71. The assessor expects that claims for human reliability should be verified, where practicable, through simulator trials and experience or alternatively using human reliability assessment methods that incorporate recognised good practice. A number of human reliability claims have been assessed and two principal concerns are highlighted. Firstly, there is no account taken of the potential dependency between subsequent failure events and secondly, meeting the requirements of recognised good practice for human reliability assessment. These factors are considered below.
72. There is no consideration of dependency issues between any of the events, either between failures of actions required to isolate a boiler and subsequent rise in pressure detection, or of dependencies between the actions and decisions across four boilers. Consideration of dependency is necessary given: the large number of actions required to undertake the necessary detection of rising pressure; the identical nature of the actions between boilers with implications for dependency; and the applicability of the claim to one or more faulted boilers.
73. In one sampled reliability analysis, as it combines cognitive and action acts in one calculation, it fails to explicitly consider or justify the impact of dependency and fails to follow the directions given within the chosen methodology. This does not follow recognised good practice.
74. Accordingly, it is considered that, based upon the available task analysis and human reliability assessment methods, and the level of justification provided, this sampled assessment may underestimate the human contribution to risk in this instance. However, it is accepted that success has been achieved in dealing with BTFs on simulators. Therefore to demonstrate the claimed reliabilities it is recommended that boiler isolation and de-isolation data that specifically identifies failures that occur during simulator exercises should be recorded.
75. The assessor is satisfied that, based on the sample examined, potential issues concerning human resources and workload both within the control room and local to plant have been satisfactorily identified and have already been addressed by changes in procedures or, where there are minor claims upon the human, are now being addressed by engineering change.
76. The assessor has made the following recommendations which would provide further confidence in both the modelling and the veracity of the qualitative evidence underpinning the claims on the operator
- ONR should observe a number of BTF fault scenarios on the simulator to consider the adequacy of the user interface to support reliable BTF task performance, the adequacy of arrangements in place to ensure personnel competence and the utility of BTF related SOIs for both Hinkley Point B and Hunterston B and usability of the BTF SOIs in practice.
  - Modelling of boiler isolation should be re-examined to confirm the appropriate treatment of the composite tasks, their internal structure, and the dependencies between actions
  - Boiler isolation and de-isolation data should be recorded and collated that specifically identifies failures occurring during simulator exercises. This should

- take account of crew variability, demonstrate the claimed reliabilities in practice and inform the modelling of boiler isolation.
- ONR should engage with NGL to examine more closely the assessment of human dependency between basic events.
- ONR should engage with NGL to better consider relevant metrics for demonstrating training effectiveness

77. The assessor considers that NGL has made the necessary human factors interventions to address the prospect of BTFs and based upon the information sampled, judged that no significant human factors issues have been identified that would prevent agreement of the safety case.

### 3.1.5 INTERNAL HAZARDS ASSESSMENT

78. This section provides a summary of the ONR internal hazards assessor's assessment (Ref. 40) of the boiler tube failure safety case (Ref. 8). The assessment focused on:

- The effect of internal hazards on the BTF case, and operator access to carry out post fault actions to manage the plant and achieve the key safety functions of shutdown, containment and adequate cooling.
- The specific issues of the depressurisation fault with consequential BTF, where there is necessarily a hot gas release to the gas circulator hall, and the adequacy of the deterministic safety case presented including the viability of claimed operator actions in areas where hot gas is likely to be present.
- The degree of confidence that NGL has in their modelling of the effects of hot gas releases, jets etc.

79. The assessment included the Licensees safety case (Ref. 8), the Consolidated Boiler Tube Failure Safety Case Keystone Document (Ref. 9) and a site visit, including a walk down of the gas circulator hall to view the important equipment and its location, and to understand the main features of the geometry of the gas circulator and turbine hall, and how this may affect hot gas and steam release flows and temperature predictions.

80. There are a number of differences in plant configuration between Hinkley Point B and Hunterston B. The assessor has concentrated the assessment on Hunterston B as the differences are generally less favourable at this station.

81. The internal hazards assessment considers:

- Effects upon reactor trip, shutdown and overpressure protection for BTF faults
- Hot gas and steam release effects in the gas circulator hall
- Effects on plant items related to the cooling capability following BTF faults
- Fault boiler isolation when the gas circulator hall is affected by internal hazards
- Whether optioneering excluded further potential improvements against internal hazards
- The credibility of claims on the operator post fault
- The effects of differences in plant configuration between Hinkley Point B and Hunterston B

82. The assessor judged that the treatment of the effects of internal hazards on reactor trip, shutdown and overpressure protection for BTF faults is reasonable. This is due to the key safety functions being only marginally affected by internal hazards, and not in ways in which the safety case would be significantly different were there to be a coincident or consequential BTF.

83. The safety case (Ref. 8) and keystone document (Ref. 9) only gives broad indicative values for the environmental conditions that could exist in the gas circulator hall

following a depressurisation fault with associated hot gas release and this is consistent with previous values of temperature, for example in the Hunterston B Consolidated Hazards Safety Case (Ref. 41). More recently, NGL have been carrying out work which has enhanced their understanding of the modelling of environmental conditions. This work includes a programme of additional computational fluid dynamics analysis. The Consolidated Boiler Tube Failure Safety Case Keystone Document (Ref. 9) indicates further sensitivity studies have been commissioned looking at differing breach sizes and locations. Overall, the assessor's view is that the current modelling is adequate for the purposes of the current BTF safety case submission, but views NGL's work programme of additional studies as important. The results may challenge the current estimates of temperature effects, but equally it may increase confidence in margins within the existing safety case.

84. There is a requirement to manage water ingress into the reactor and prevent water pooling to the extent that it prevents gas flow at the bottom of the boilers / gas circulators, whilst at the same time enabling feed to unaffected boilers. A process of fault boiler isolation is carried out, to identify and isolate a leaking boiler. Once this is achieved, unaffected boilers can provide ongoing cooling, without further water ingress. The assessor considered that the combination of a multiplicity of options for boiler venting, coupled with the work NGL are carrying out to clarify operating procedures and require early boiler blowdown to atmosphere, will lead to improved margins in the BTF safety case.
85. The assessor considered whether boiler isolation could be achieved during fires, steam release and flooding hazards contingent on or coincident with BTF's. Based upon the arguments and evidence presented the assessor is content with the consideration of fire hazards and steam release within the Consolidated Boiler Tube Failure Safety Case Keystone Document (Ref. 9). The judgement of the assessor is that the internal flooding is a complicating feature of accident management, but does not greatly affect the overall case and is not a significant additional concern.
86. The ALARP assessment in Appendix C of the keystone document (Ref. 9) considers additional options for reducing risk. The assessor has reviewed this optioneering and is content with the improvements identified against the challenges of the current BTF safety case, and that NGL haven't rejected practicable options because risk estimates have taken undue weight above relevant good practice.
87. The credibility of claims on the operator in the case of BTF consequential on a depressurisation fault and consequential BTFs following other hazards, such as fires and steam release were examined. The assessor is content with the safety case presented provided the conditions within the gas circulator hall recover to acceptable conditions compatible with the timescales for action.
88. To conclude, the internal hazards assessor is broadly satisfied with the claims, arguments and evidence laid down within the Licensee's safety case for the aspects covered by the assessment, which relate to the relationship between the internal hazards safety cases and those for boiler tube failure.
89. Two regulatory issues have been raised on the ONR issues database:
  - ONR should monitor the Licensee's current work programme of comparative analyses of hot gas releases using bulk models and more detailed computational fluid dynamics models.
  - ONR should sample more severe fires and hot gas releases as part of the assessment of internal hazards aspects of the Hinkley Point B and Hunterston B periodic safety review to assure ONR that there is not a "cliff edge" and that the safety case is secure.

90. Despite raising these issues, the assessor was content that the treatment of the hazards within the boiler tube safety case was adequate and there are benefits from the implementation of the work programme of improvements.
91. On the basis of the assessment of internal hazards aspects of the BTF safety case (Ref. 40) and its supporting references, the assessor recommended that ONR issue an agreement to enable the Licensee to implement the safety case and to continue with their planned work programme of improvements.

## **3.2 LICENSEE'S ARRANGEMENTS**

### **3.2.1 VERIFICATION STATEMENT**

92. NP/SC7703 (Ref. 8) underwent NGL verification at versions 002 and 005. The case was accepted on both occasions with only minor comments. This document is mainly supported by a keystone document DAO/REP/JICC/040/AGR/10 Revision 002 (Ref. 9), which presents the full safety justification. As such, the verification of the keystone document (Ref. 9) is an intrinsic aspect of the verification of NP/SC7703 (Ref. 8).
93. Verification of this NP/SC7703 (Ref. 8) has therefore primarily focussed on the accurate representation of the arguments and evidence presented in the keystone document (Ref. 9), and the evolution of the overall safety case position from Phase 2a to Phase 2b.
94. NP/SC7703 (Ref. 8) and the keystone document (Ref. 9) present the aggregation of many workstreams progressed by the boiler tube failure safety case programme, and verification largely focussed on the accurate representation of the development of these workstreams in a clear and structured format.
95. Judgements regarding the tolerability of the residual risk, especially that associated with depressurisation faults with a consequential boiler tube failure, and the proposed commitment to pursue further risk reduction measures where reasonably practicable, are supported.
96. In conclusion, NP/SC7703 (Ref. 8) was judged to be fit for purpose by NGL's verification process and an accurate representation of the current status of the boiler tube failure safety case.

### **3.2.2 INDEPENDENT NUCLEAR SAFETY ASSESSMENT**

97. An NGL Independent Nuclear Safety Assessment (INSA) approval statement was provided on 14 December 2015 for NP/SC7703 (Ref. 42). INSA have reviewed NP/SC7703 (Ref. 8) and the keystone document (Ref. 9). The preceding version of this case was presented for INSA in 2012 and significant portions have not changed. Where this is the case then cognisance has been taken of the previous INSA.
98. There are a number of plant modification workstreams that have been proceeding since the preceding version of the BTF safety case was presented. Independent Nuclear Assurance (INA) has maintained ongoing oversight of these workstreams and this has informed the INSA of this submission.
99. Two of the outstanding modifications, CO<sub>2</sub> instrumentation at Hinkley Point B and work on CO<sub>2</sub> plant at Hunterston B, which deliver significant nuclear safety benefit are not due to complete until 2017. INA are therefore intending to maintain enhanced oversight of these modifications to ensure that appropriate focus is maintained by the stations. Additionally INA will continue to press for progress in completion of associated and additional process modifications.

100. INA are inline to review the completion of existing commitments where they are significant to nuclear safety.
101. I have sampled the INA comments (Ref. 43) on the safety case (Ref. 8) and am generally content that they have been addressed appropriately.

### **3.2.3 NUCLEAR SAFETY COMMITTEE**

102. The BTF safety case (Ref. 8) was presented to the Nuclear Safety Committee (NSC) in November 2015 (Ref. 44) by the Technical and Safety Support Manager (TSSM) for Hinkley Point B power station. Additional support was provided by the verifier, case officer and INA representative.
103. The subsequent discussion questioned whether additional protection could be provided to avoid the required operator actions during a fault condition. While this had been considered it was difficult to avoid but reactor blow down from the control room would maximise the time available for remedial action. Concern was expressed with claims on the operator to respond to the Effective Reactor Gas Mass (ERGM) alarm within 20 minutes. It was indicated that the first line of protection was automatic and the operator action is claimed as the second line of protection. Additionally this action time is related to the bounding fault thus the available time for other faults would be greater. Additionally the operating procedure actually looked for a positive confirmation for an absence of the ERGM alarm.
104. Concern was raised that putting the commitments identified in Table 3 of the BTF safety case (Ref. 8) into 'normal business' may result in them not being carried out. The case officer indicated that the actions will be appropriately prioritised with other nuclear safety work plus progress would be monitored.
105. Concern was raised with respect to the current oil leaks on two gas circulators but it was appreciated that it was not appropriate to shut down the reactor to address them. The concern was due to the potential for a BTF to result in water entering the lubrication system.
106. Clarification was sought as to the future inspection proposals for the bifurcations. It was confirmed there would be 100% inspections of accessible cardinal positions with 100% verification.
107. He observed that safety cases are built on prevention and mitigation. It was noted that the document focused on the mitigation more than prevention. This gave the overall impression of an imbalance in the importance being applied to the two legs of the case.
108. The NSC was uncomfortable with claiming benefit from work not yet completed, however concluded that it was a good point to provide an update to the case. A report was requested on the status of the outstanding BTF safety case work at Hinkley Point B and Hunterston B.
109. Confirmation was requested that the updating of the Station Operating Instructions (Sols) would be completed before the due date of 2017. It was indicated that the aim was to complete the work as soon as practicable, but well before 2017.
110. The NSC noted the huge achievement in the preparation of this case and generally considered it to be good and noted that there was no formal advice or significant points for consideration relating to the safety case (Ref. 8).

### **3.3 ONR PROCESS**

111. To support this permissioning I have:
- Utilised the services of the ONR specialist inspectors assigned to this project by the ONR operating facilities programme management team, taking cognisance of their conclusions and recommendations.
  - Considered NGL's safety case verification statement
  - Considered the resolution of NGL INSA comments and the issuing of the NGL INSA statement
  - Considered NSC comments and its overall support for safety case
112. I have drawn upon the ONR specialist inspectors' considerations and recommendations in the areas of structural integrity, fault studies, PSA, human factors and internal hazards.
113. Each discipline has produced a report presenting their assessment findings, opinions, judgements and recommendations. All assessments were undertaken in accordance with the requirements of the ONR How2 Business Management System (BMS) guide Purpose and Scope of Permissioning (NS-PER-GD-014, Rev 4 (Ref. 45)).
114. All of the specialist inspectors' assessment reports have undergone independent peer review and formal approval via the respective professional leads in accordance with ONR How2 BMS guide Peer Review for Technical Assurance (NS-TAST-GD-085, Rev 4 (Ref. 45)) which supports the approach taken, conclusions raised and recommendations made by the specialist inspectors.
115. All of the ONR specialist assessment reports contain either a statement supporting the proposed activity, or note that there is no reason to withhold permission for the proposed activity.

### **3.4 REGULATORY CONSIDERATIONS**

116. ONR should, subject to assessment, provide an Agreement under EdF Energy NGL derived powers and licence condition 22(1) to the Boiler Tube Failure Safety Case Phase 2b Consolidation (Ref. 8).
117. Development of the safety case and implementation of modifications has been carried out in several phases over a significant time period. While ONR have taken a regulatory view of significant parts of the safety case it is considered appropriate, now the case is in its final state, to take a holistic view and consider whether the consolidated case is satisfactory. This is the basis on which the decision was made to carry out an assessment of the consolidated safety case with a view to providing an agreement under derived powers.
118. The Agreement will be on the basis of the evidence sampled and that the outstanding commitments in Tables 1 and 2 of Ref. 8 are completed in a timely manner.

## **4 MATTERS ARISING FROM ONR'S WORK**

119. In order to form a view on the adequacy of the claims, arguments and evidence presented a number of specialist inspectors from structural integrity, fault studies, PSA, human factors and internal hazards have assessed the case.
120. Although the NSC expressed some discomfort with claiming benefit from work not yet completed regular progress meetings are held between ONR and NGL to review progress with the commitments made in the BTF safety case. I am generally content that progress is being made in their delivery. Additionally, a regulatory issue has been raised to continue to monitor progress as indicated below.

121. While generally the assessors were in agreement that the case was fit for purpose a number of points / issues were raised that need to be addressed. These included:
- That the outstanding commitments should be completed in a timely manner and that ONR monitor progress.
  - That ONR monitor the potential implications of carburisation on the safety case for boilers at Hinkley Point B and Hunterston B.
  - To ensure predictions remain valid periodic inspections of boiler components should continue at appropriate intervals.
  - That ONR considers the Licensee's safety case for BTFs on a shutdown reactor when completed.
  - That ONR engages with NGL to review the development and use of PSAs to end of station life, focusing on the use of best estimate data and analysis where possible.
  - That ONR considers the need to undertake further assessment of the risks from BTFs during refuelling operations as part of continued oversight of the BTF safety case.
  - That ONR should observe a number of BTF fault scenarios on the simulator to consider the adequacy of the user interface to support reliable BTF task performance, the adequacy of arrangements in place to ensure personnel competence and the utility of BTF related SOIs for both HPB and HNB and usability of the BTF SOIs in practice.
  - That modelling of boiler isolation should be re-examined to confirm the appropriate treatment of the composite tasks, their internal structure, and the dependencies between actions
  - That boiler isolation and de-isolation data should be recorded and collated that specifically identifies failures occurring during simulator exercises. This should take account of crew variability, demonstrate the claimed reliabilities in practice and inform the modelling of boiler isolation.
  - That ONR should engage with NGL to examine more closely the assessment of human dependency between basic events.
  - That ONR should engage with NGL to better consider relevant metrics for demonstrating training effectiveness
  - That ONR monitor the Licensee's current work programme of comparative analyses of hot gas releases using bulk models and more detailed computational fluid dynamics models.
  - That ONR sample more severe fires and hot gas releases as part of the assessment of the Hinkley Point B and Hunterston B periodic safety review to gain assurance that there is not a "cliff edge" and that the safety case is secure.
122. Where appropriate these issues have been included on the ONR issues database and will be subject to review at regular intervals by the appropriate specialist inspector.

## 5 CONCLUSIONS

123. EdF Energy Nuclear Generation Limited (NGL), has requested (Refs. 1 and 2) an Agreement or Acknowledgement under LC22(1) to the modification described in the Boiler Tube Failure Safety Case Phase 2b Consolidation (Ref. 8).
124. This report presents an assessment of the Hinkley Point B and Hunterston B Consolidated Boiler Tube Safety Case (Ref. 8). It is supported by assessments from ONR specialist inspectors for structural integrity, fault studies, PSA, human factors and internal hazards.

125. Based on the structural integrity assessment (Ref. 14), I am satisfied that the risk of future leaks has been reduced to ALARP I am also content that the methods for establishing the likelihood and magnitude of BTFs used in the consolidated BTF safety case are appropriate given that they are based upon sound engineering principles and methodologies and a conservative guillotine failure fraction.
126. Based on the fault studies assessment (Ref. 33), I am satisfied that the safety case is consistent with the relevant ONR standards and guidance. I am also content that sufficient post BTF shutdown margin is available at the higher core average graphite weight loss and agree that the plant modifications are consistent with the safety case in terms of defence against BTF and mitigation of the potential consequences.
127. Based on the PSA assessment (Ref. 38), I am satisfied that the safety case provides sufficient evidence to demonstrate adequacy of the PSA claims.
128. Based on the human factors assessment (Ref. 39), I am satisfied that no significant safety shortfalls have been identified with the human factors aspects of the BTF safety case.
129. Based on the internal hazards assessment (Ref. 40), I am satisfied with the claims, arguments and evidence laid down within the Licensee's safety case which relate to the relationship between the internal hazards safety cases and those for BTF.
130. Having taken into account the opinions of the ONR specialist inspectors, I consider that there are no issues that prevent ONR issuing the requested agreement.
131. The Agreement is on the basis of the evidence sampled and that the outstanding commitments in Tables 1 and 2 of Ref. 8 are completed in a timely manner.

## **6 RECOMMENDATIONS**

132. Based on the assessment undertaken, it is the recommendation of this PAR that the superintending inspector should:
  - sign this project assessment report, confirming support for the ONR technical and regulatory arguments used to justify issuing Hinkley Point B LI555 and Hunterston B LI555; and
  - sign Hinkley Point B LI555 and Hunterston B LI555.
133. ONR should monitor the regulatory issues raised during assessment of the safety case (Ref. 8) to ensure outstanding commitments are completed and that the validity of the safety case (Ref. 8) is not significantly undermined.

## 7 REFERENCES

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